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Fourth Annual Report

Southwestern Public Service Co., Amarillo, TX

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Fabric Filter System Study:

Fourth Annual Report

by

R. L. Chambers, O. C. Plunk, and S. L. Kunka
Southwestern Public Service Company
P. O. Box 1261
Amarillo, Texas 79170

Contract No. 68-02-2659

EPA Project Officer: Dale L. Harmon

Industrial Environmental Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, NC 27711

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVLEOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT The report gives results of the fourth year of operation (ending October 1, 1981) of a fabric filter installed by Southwestern Public Service Co. on its Harrington Station Unit 2 coal-fired boiler in Amarillo, Texas. Project work during the fourth year concentrated on fabric studies. The 10-oz/sq yd fabrics of the 150 1/2 warp, 150 2/2T fill construction demonstrated superior performance over the most common 14-oz/sq yd constructions, regardless of coating. It was determined that improving cleaning by increasing shaking amplitude is more detrimental to baglife than increasing shaker frequency. Maintenance and operation observations continued, and the resolution of these types of problems became more efficient because of increased experience of maintenance personnel with baghouse-related problems.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Filtration	Stationary Sources	07D
Fabrics	Fabric Filters	11E
Particles	Baghouses	14G
Electric Generators	Particulate	10B
Coal		21D

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ABSTRACT

The fourth year of study on the fabric filter system at Harrington Station ended October 1, 1981. Project work during the fourth year concentrated on fabric studies. Maintenance and operation observations continued and the resolution of these types of problems became more efficient because of increased experience of maintenance personnel with baghouse-related problems.

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CONVERSION TABLE

To Convert From	To	Multiply By
Btu/lb	joules/kg	4186.8
°F	°C	(°F-32)/1.8
ft	m	0.305
gr/scf	gm/m^3	2.29
in.	cm	2.54
in w.g.	mm Hg	1.87
lb	gm	454
miles	km	1.609
oz.	grams	28.350
Btu	joules	1055
ppm	mg/liter	1.0
cfm	cubic meters/hr	1.699
ft/sec	centimeters/sec	30.48
sq. ft.	sq. meters	0.093
lbs. of tension	newtons	4.448
stack pressure in Hg	kg/cm^2	0.035
$wscf/10^6$ Btu	wscm/joule	$2.6x10^{-11}$
$lbs/10^6$	nanogram/joule	433.3
lbs/wscf	$micrograms/m^3$	$16.018x10^8$
ft^2	$meters^2$	0.093

I. INTRODUCTION

The fourth year of work on the fabric filter system study being conducted by Southwestern Public Service Company (SPS) for the U.S. Environmental Protection Agency (EPA) ended October 1, 1981. The objective of this project is to make a comprehensive study of a fabric filter system used for particulate collection on an electrical generating unit that utilizes low sulfur, Western coal.

SPS is an electric utility headquartered in Amarillo, Texas. The company has a generating capacity of 3,773,000 kw and serves customers in Texas, Oklahoma, New Mexico and a small area of Kansas. Harrington Station, where the study is being performed is SPS's first coal-fired plant. A second coal-fired plant is now on line in Lamb County, Texas.

Project work during the fourth year of study concentrated on fabric studies. Maintenance and operation observations continued and the resolution of these types of problems became more efficient because of increased experience of maintenance personnel with baghouse-related problems.

Fabric wear patterns were studied closely during the fourth year. Certain test fabrics were installed for an in-depth analysis. Inspections were made on a regular basis and records of fabric failures were maintained. For in-depth analysis, bag samples were periodically sent to an outside consulting firm for specialized tests. This fabric experience will be of value to other utilities selecting cloth for ash types similar to Harrington Station's.

II. SUMMARY AND CONCLUSIONS

1. Studies indicate that within limits the same cleaning can be obtained by varying shaker speed and amplitude in opposite directions according to

$$a = f^2 A$$

where a is the fabric acceleration, f is the shaking frequency and A is the amplitude of shake. From observations of the shaking motion and laboratory analysis of failed fabric, it is apparent that the amplitude of shake is the more detrimental to baglife. These results indicate that shaking amplitudes smaller than 1.5 inches would increase fabric life.

The level of deflation has been found to be surprisingly important. At the extremes, too much deflation collapses the bags and causes poor cleaning and fabric damage; with too little deflation, the fabric does not clean sufficiently, resulting in high pressure drop. Proper control would be easier to maintain by controlling deflation gas flow rather than pressure drop.

2. Fabric choice plays a central role in determining both pressure drop and baglife. Fabrics which clean better have to be cleaned less frequently and therefore last longer. More protective coatings and more adequate constructions are capable of sustaining the effects of cleaning for longer periods of time. The data collected at Harrington Station have not been sufficient to determine the optimum fabric for a specific application; however, the 10-oz/yd^2 fabrics of the 150 1/2 warp, 150 2/2T fill construction have demonstrated their superiority over the most common 14-oz/yd^2 constructions, regardless of coating.

Over the lifetime of the fabric no appreciable difference has been discerned between acid-resistant coated fabrics and Teflon-coated fabrics on either the 10- or 14-oz/yd^2 fabrics in terms of pressure drop performance.

Fabric life at Harrington, however, has been appreciably better with the Teflon coatings on 10 oz. materials.

Experience with synthetic fabrics has been limited to two styles of 5.5-oz/yd^2 Nomex materials. One of the fabrics, a 3x2 twill Allspun fabric, has shown remarkably higher flow and lower pressure drop compared with the glass fabrics. The other fabric, a 3x1 twill combination material has performed at the same level of pressure drop and flow as the glass fabrics.

Future work in optimizing cleaning and fabric life will concentrate on reducing shake time and the evaluation of certain commonly available fabric constructions.

3. The procedures adopted at Harrington have proven to be successful with no problems having been credited to improper start-up or shutdown procedures since the unit came on line in 1978. For application to other units the procedures used at Harrington may require modification due to higher sulfur contents in certain coals, lower operating temperatures, and lack of alkalinity in the fly ash. To overcome some of the problems associated with higher sulfur operation longer warm-up periods may need to be employed during start-up and a longer flue gas purge during the shutdown.

4. Good maintenance and inspection procedures are necessary to maintain an awareness of the current state of operation, to detect developing problems, and to perceive the opportunities for improving operation. Good recordkeeping has proven to be beneficial in resolving recurring problems and in judging baghouse performance from a historical perspective.

III. OPERATION

A. Pressure Drop History

The pressure drop history for Harrington Unit 2 since rebagging in the summer of 1979 is shown in Figure 1. Only two points are shown for the 1980-1981 reporting period. During this period, plugging problems with the annubar flow meters were encountered leading to the collection of 10 months of suspect data. The problem was finally resolved with the installation of a high pressure back flush line to allow the device to be cleaned on a monthly basis.

From the two data points that were recorded, it appears that no significant change in pressure drop occurred from the previous year. Although a proper assessment of the increase in pressure with time-in-service will have to await more data, the results so far are very encouraging.

B. Optimization

During the fourth year of study, the following changes were made to the cleaning cycle:

January:	West cleaning cycle-5 inches w.g. or 60 minutes rest.
February:	West cleaning cycle-5 inches w.g. or 150 minutes rest.
May:	East cleaning cycle-5 inches w.g. or 250 minutes rest.
August:	West shaker timer-decreased from 20 seconds to 15 seconds.

By the end of the year, it was apparent that cleaning on 5 inches w.g. or 150 minutes had not caused the pressure drop to deteriorate compared to continuous cleaning. This modification will mean fewer total cleaning cycles will be involved during the year. The effect on bag life is expected to be significant considering the number of hours the unit spends at low loads.

A test begun in August with decreased shake time has shown encouraging results. The shaker times have been cut back from 20 to a 15-second shake

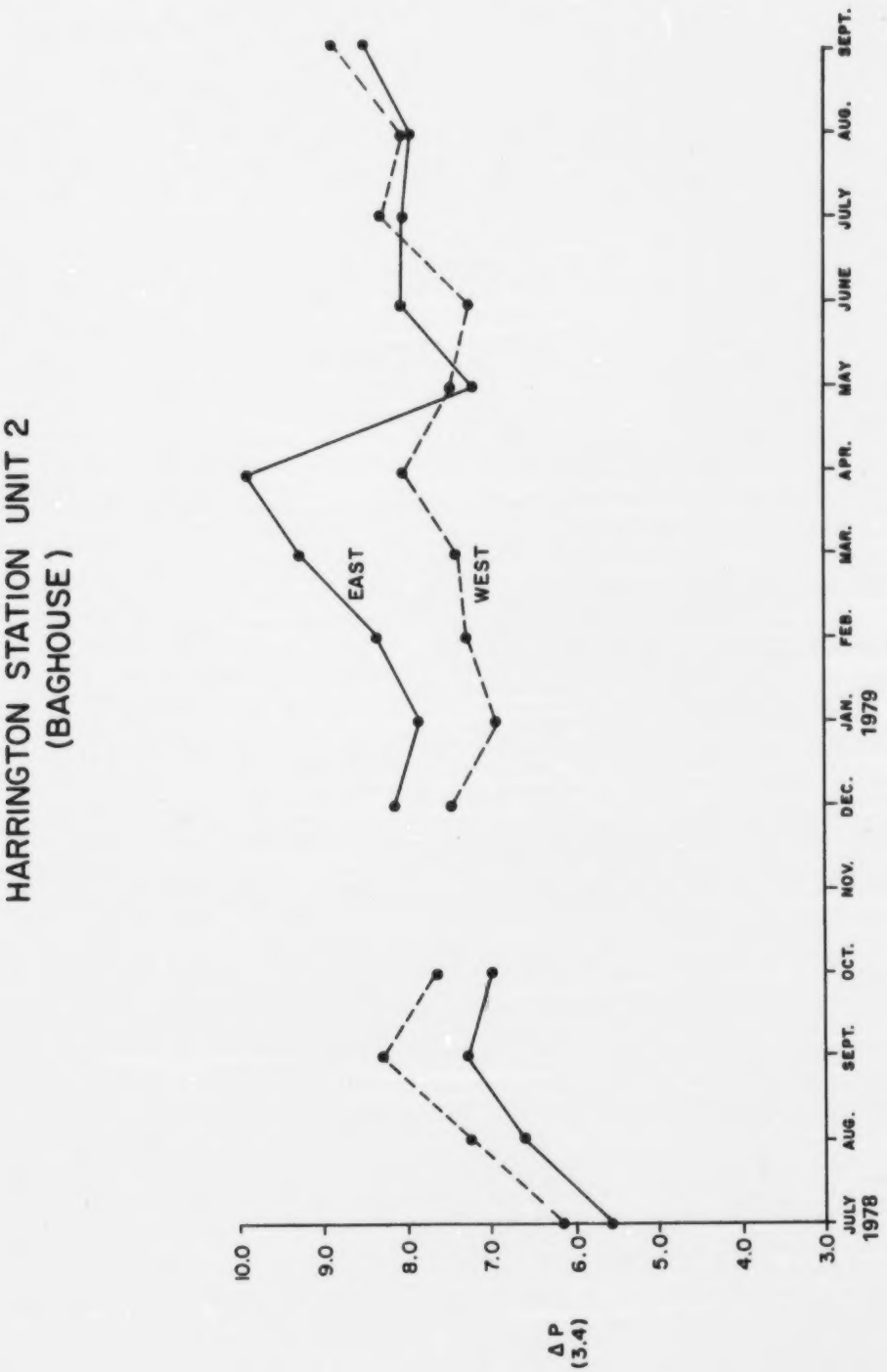

Figure 1. Harrington Unit 2 Pressure Drop History

without affecting pressure drop. This program will be continued to find the minimum shake time allowable before the pressure drop starts to deteriorate. A significant increase in bag life should result from these modifications without a pressure drop penalty.

C. Start-up and Shutdown Procedures

After a review of problems associated with start-up and shutdown, a set of procedures were established and they have proven successful for Harrington Units 2 and 3. The baghouse is started up on bypass to heat the unit before operation in order to avoid corrosion and wetting the cementitious ash.

Baghouse Cold Start-up (hopper heaters must be put into service 24 hours before start-up, 220°F).

1. Inspect compartments.
2. Close all three doors.
3. Close ventilation system dampers.
4. Put both top and bottom isolation switches to operate position.
5. Energize outlet damper breakers.
6. Check shaker, deflation, recirculation, and reinflation breakers to see that they are energized. (All dampers should have an open, closed, or travel light.)
7. Make sure fly ash hopper poke-out caps are on tight.

Baghouse Start-up At Inlet Temperature of 220°F.

1. Open inlets. (Manual chain driven butterfly dampers.)
2. Close bypass dampers one at a time, alternating east and west sides. (This will be done when temperature reaches 220°F. Advise foreman of action taken.)
3. Wait for opacity to settle to normal (STABLE LINE).
4. Start deflation fans.
5. Start cleaning cycle as needed - inform foreman. (Turn circuit control power on, put cleaning cycle to auto.)
6. Start fly ash system.

Baghouse Hot Start-up (inlet temperature not below 150°F; main gas not put in).

1. Follow steps 2 thru 5 of baghouse start-up at inlet temperature 220°F.
2. If inlet temperature drops below 150°F, go to baghouse normal scheduled shutdown procedure.

Baghouse Normal Scheduled Boiler Shutdown.

1. Leave baghouse on line until inlet temperature drops to 220°F.
2. Stop both cleaning cycles.
3. Stop both deflation fans.
4. At 250°F (lower limit 220°F) open bypass dampers, one on each side until all eight are opened. This will be done from baghouse control room. (These bypass dampers may be opened from the main control room, but in this case all the dampers will open at once on the side being bypassed.)
5. Close manual inlets (chain-driven).
6. Trip isolation switches. This will close outlet dampers, reinflation dampers, and lockout deflation dampers and shakers.
7. Leave ID fans on for boiler cool down as directed by foreman.
8. Leave fly ash system in operation for one complete cycle after cleaning system is shut down or until ash hoppers are clean (visual inspection).
9. Open and secure all doors. This will be done when instructed by foreman.
10. Start vent fan--inspector or maintenance option.

In the shutdown procedure the flame is out in the boiler at temperatures in the 240°-250°F range (@35 Mw). For approximately 20-30 minutes the baghouse is purged with warm air being drawn through the boiler to sweep out any remaining flue gas, thereby preventing condensation. For boilers operating with coals of higher sulfur and lower calcium content, the procedure may need amending to allow for a longer purge at higher temperatures. In addition, higher sulfur coals would also require longer preheating and higher temperatures before initiating start-up.

D. Operation Log

December 1980:

Maintenance - Shaker failures occurred ten times. Flangette bearings were changed on two compartments and four dampers failed.

Fabric - All Criswell 449-I580 and 449 COF fabrics were determined to be at the end of their useful lives and were to be replaced as soon as possible. Twenty-six blowout failures occurred, mostly in these fabrics. Because of this high failure rate, shakers for compartments 16, 18, 26, and 28 were turned off. These compartments were being cleaned once or twice daily.

January - February 1981:

Operations - The high-temperature trip was changed on January 7 from 500°F to 425°F because Nomex bags could not withstand a higher temperature.

The west cleaning cycle was set to clean at 5 inches pressure drop with a 60-minute rest instead of continuous, regardless of load. Changes were made on January 20 to save bags, shakers, and damper drives. Due to timer problems, this modification has not yet proven successful; however, the "bugs" are being worked out.

Shaker sheave 8 was changed out because of continuous failure; a 6-inch sheave was replaced with a 5.3-inch sheave.

The 150-minute rest timers became operational on February 14. Cleaning was set at either 5 inches w.g. or 150-minute interval on the west side. This cleaning cycle appears to be working well; the effect of high load operation will be closely observed.

Maintenance - At the beginning of January, the Unit 2 baghouse was operating with two shakers out for maintenance, one compartment isolated on stand- by, and five shakers energized to preserve worn bags.

Compartment 27 was taken out of service for rebagging with Fabric Filters 504-1 Tuff Coat and returned to service. Compartment 25 was also rebagged with Criswell 442 COF-II and returned to service; compartments 15 and 25 were inspected for blown bags and three were replaced.

The west deflation fan failed and flow from the east fan had to be crossed over to service both east and west deflation needs. The west

deflation fan remained out of service through the end of January. A standard outlet, deflation, reinflation, and recirculation damper drive inspection was also conducted during this period.

Shakers 8, 11, 12, 21, 20, and 2 failed in February. In addition, one deflation damper was stripped and one outlet damper drive was changed out. Other equipment out for maintenance in February included the west deflation fan, outlet dampers 23, 24, and 26, and shakers 65, 11, 12, 20, 21, 23, and 25.

Compartment 25 was inspected in February to check the condition of new bags installed in January. The Criswell 442 COF-II bags looked good. One bag was removed from compartment 20 for testing by Gore.

In February, numerous manometer lines near the baghouse control room froze. Opening the piping boxes allowed heat from the control room to warm lines. Annubar flow meters and pressure drops for both sides of the baghouse were calibrated. However, after calibration, air-to-cloth ratios were still unsatisfactory.

March 1981:

Operation and Maintenance - At the first of March, The Unit 2 baghouse had two shakers out for maintenance and four shakers out of service to save worn bags in compartments 16, 18, 26, and 28.

Seven other shaker problems were detected during an inspection on March 16, 1981. Four of them were to be rebuilt; the shaker tube Flangette bearings were to be replaced with pillow bearings. Eccentrics were to be changed out when necessary. The east deflation system was running in manual mode during March and the auto control was not working.

Five bag failures occurred in March. Four new compartments of bags were put on-line with loads below 200 Mw. The new bags were not cleaned for 12 hours in order to establish a cake build-up on the new fabric. All reinflation and outlet dampers were checked for proper sealing. Some leakage to the ID fan was detected in 13 of 28 compartments.

Overall status of the Unit 2 baghouse appeared better at the end of March than it had in several months. All worn bags had been replaced and 16 compartments had shaker tube pillow block modification completed. Four

compartments were being modified and the remaining eight were to be done as time permitted.

April 1981:

Operation and Maintenance - Five shaker problems were detected during an April 21 shaker inspection. Shakers 6, 12, 15, 17, 23, and 25 were rebuilt. Shaker tube Flangette bearings were replaced with pillow bearings and eccentrics were changed out when necessary.

The bag failure rate for April was considerably higher than normal. Some compartments had to be taken out of service to repair outlet damper damage (sixteen blown bags, one ruined outlet damper).

Six compartments of Flangette modifications remained to be made as soon as possible. An outlet damper change-out to replace faulty Joyce Cridland drives was scheduled for May.

May 1981:

Operations - The majority of fabric installed during the summer of 1979 was showing obvious signs of wear. Twenty compartments of fabric were ordered (10 oz., 10% Teflon-coated fiberglass.) Five compartments were to be sent immediately and the other 15 were placed on a 6-month make and hold agreement with the manufacturer. Several fabrics have indicated superior performance. These are the 1) Menardi Southern 601T, 10 oz., and 2) Criswell 44257DC2, 10 oz. These fabrics will be left in place until approximately 10% failure has occurred.

Shaker failures increased in May. Most were on the west side of the baghouse which has experienced increased pressure drop.

Cleaning cycle timers were checked and set when necessary. The east rest timer was set to 150 minutes; both rest timers are currently running the same.

Maintenance - Twenty-six bag failures occurred in May. These 26 failures took place in six different compartments with one repeating twice. An outlet damper drive change-out was completed in May; the old ones were to be returned to Joyce Cridland.

The May shaker inspection revealed nine maintenance requests with ten

problems. Three problems were too major to allow shakers to continue shaking without maintenance, so they were de-energized on instruction cards. Another shaker failed altogether. All 11 shakers were to be repaired when manpower became available.

June - July 1981:

Operations - New fabric for five compartments was received in June; bags for fifteen additional compartments will be sent as soon as they have been fabricated.

The number of compartments taken out to tie off or change out bags make it difficult to maintain equal gas flows to each side of baghouse. Most failures occurred on the east side in July, making pressure drop look worse than normal. Cleaning cycle times were checked and adjusted. Shake operation appeared to be improving. Only four Flangette modifications remain to be made.

Maintenance - Four shakers were out for maintenance and one was taken out of service to preserve worn bags. At the end of June, one maintenance problem and one Flangette modification was in progress. Twelve bags blew out in seven different occurrences; compartments 22 and 24 each had two blowouts. Eleven shaker problems from May were repaired; however, eleven more developed. Six of these were detected during the monthly shaker inspection and all but one was fixed.

The west deflation timer was down for three days due to a stripped out limit switch. A coupling was ruined on the east deflation fan when the baghouse was started-up following a tube leak shutdown. The problem was repaired within three days. In addition, the east inlet temperature to the baghouse was found to be 64°F different from the computer reading. Parts were ordered to resolve this problem.

Two shaker problems occurred and one Flangette modification was in progress. Four shakers were repaired. Twenty-five blown bags occurred in July in seven different compartments. Compartments 21, 22, and 24 had repeated failures (accounts for 14 of 24 failures). Compartment 22 has an 11.27% failure rate, which is the worst record of bag failures. All other compartments are in the less than 7% failure range. Currently, 15 bags are

tied off and will remain tied off until a compartment change-out occurs.

August 1981:

Operation - Two Flangette bearing modifications remained to be done at the end of August. One was in progress and plans were to complete both during the upcoming annual outage. The west shaker timer was decreased from 20 seconds to 15 seconds in order to spare bags and shakers without giving up pressure drop. This experiment will continue three months or until signs of increased pressure drop appear.

Maintenance - Nine shaker failures were recorded in August. Twelve bag failures occurred in three compartments (two of the three compartments had repeated failures). Several pre-overhaul inspections were conducted. These inspections included shakers, damper drives, and all baghouse doors. Six to eight compartments of bags were scheduled to be replaced during the annual outage. The bags were 26 months old, except two. One was 31 months old and the other was 21 months old. Twenty-two sample bags were removed August 29 for special testing by Environmental Consultants.

September 1981:

Operation - The Unit 2 baghouse was put back in service on September 24 following its annual outage. The post overhaul start-up went well. Unit load was held to 150-160 Mw for the first 24 hours to "season" the six new compartments of bags installed during the outage. The new fabrics were put into service with compartment shakers energized and cleaned once at the end of 24 hours. A cleaning schedule was then established to shake once at 8 inches of pressure drop across the cloth. This schedule is to be maintained for one week before going to a normal cleaning cycle. The remaining 22 compartments were cleaned once after 24 hours and then put on a cleaning cycle of one shake at 7 inches pressure drop across the baghouse until September 28, 1981.

Maintenance - The west deflation fan failed to start after the outage due to dirty contacts. The east deflation controller failed to drive after the outage and had to be rebuilt. This controller was back in service by October 1.

IV. MAINTENANCE

A. Inspection Procedure

SPS performs an annual overhaul on all of its generating units. During this period of time a thorough inspection is performed on the baghouses at Harrington. Much of the baghouse inspection can be done with the unit on-line and is performed as a pre-overhaul inspection.

During the inspection, an evaluation of fabric condition is made to observe wear patterns and overall condition. Data from this evaluation are used to compare various fabric types and determine when replacement fabrics should be purchased. The inspection forms used at Harrington are shown in Figures 2 and 3.

Results of the 1980 annual overhaul are described below.

B. Inspection Summary

Ductwork - Inlet ductwork appeard to be in good condition with no signs of corrosion. There were no accumulations of ash, except at the stack end of the inlet duct. Unlike previous inspections, ash piles were observed just upstream of the last set of inlet dampers on both ducts.

Compartment Inspection - Corrosion due to inleakage was noted in several compartments. The upper northeast corner in compartment 2 leaked considerably. Water marks were evident on the bags and the floor. Signs of inleakage were also noted in compartments 7, 8, 10, 11, 12, 14, and 15. On interior walls, some corrosion was evident. This is probably due to the fact that insulation stops short of covering the entire roof over the interior compartment wall and thus some condensation had occurred.

Shaker Tube Motion - Evidence of the axial motion of the shaker tubes was found in some compartments.

Fallen Bags - A fabric inspection revealed two fallen bags. Both bags had worn through the J-hooks. J-hook wear has been severe in a few cases

but is not a serious problem at this time.

Bag Tension - Bag tension was less than 60 pounds on all compartments, except 6 and 21. Only three compartments were so loose that "dropping" over the thimble appeared to be a problem. Compartments 1, 22, and 23 were retensioned.

Fabric Inspection - In general, fabrics looked very good. Mechanical damage destroyed a total of 79 bags. Shaker tubes in compartments 19, 22, 23, and 24 stopped, causing bags in adjacent rows to collide with bags on the immobile shaker tube.

Inspection of compartments 16, 18, 25, 26, 27, and 28 revealed that the severe wear patterns previously observed had continued to worsen. The fabric appeared to be near termination of its useful life. Severe damage on fold lines caused a series of pin holes down the bag.

FIGURE 2. PLANT EQUIPMENT INSPECTION FORM

(BAGHOUSE)

Date_____ Baghouse_____ Plant_____

Manufacturer_____ Year Built_____

RECORD OF INSPECTION

1.DUCT WORK_____ INLET

Is corrosion present?_____

What % of surface is affected?_____

Is corrosion slight or serious?_____

Record cracked welds in bracing._____

Does duct need cleaning?_____

What is the condition of expansion joints?_____

Comments:_____

_____

2. DUCT WORK_____ OUTLET

Is corrosion present?_____

What % of surface is affected?_____

Is corrosion slight or serious?_____

Record cracked welds in bracing._____

Does duct need cleaning?_____

What is the condition of expansion joints?_____

Comments:_____

_____

3. Bypass dampers_____ SIDE

Are bypass dampers heating?_____

Describe if not._____

Is corrosion present?_____

Describe_____

Signs of wear on seat or disc?_____

Describe_____

Comments:_____

_____

4. DEFLATION FAN_____ SIDE

Packing leaking?_____

Describe general appearance of connecting duct work._____

_____

_____

Comments:_____

_____

_____

5. TUNNEL FANS_____ SIDE

Are fans quiet?_____

Are seals leaking?_____

Comments:_____

_____

_____

_____

_____

6. CELL PLATE LEVEL Compartment #_____

Are door seals leaking?_____ Describe_____

_____

Do outside doors latch?_____ Describe_____

_____

Are bags tensioned properly?_____

Describe and locate_____

_____

Are bags in good condition?_____

If broken fibers, where?_____

If bleeding, where?_____

Ash accumulation on floor?_____

Describe and locate_____

_____

Ash accumulation around walls?_____

Describe and locate_____

_____

Signs of moisture or corrosion on walls?_____

Describe and locate_____

_____

Broken welds?_____

Describe and locate_____

_____

Comments_____

_____

_____

7. SHAKER LEVEL Compartment #_____

Are door seals leaking?_____

Describe_____

Do outside doors latch?_____

Describe_____

J hooks and compression springs in good condition?_____

Describe and locate_____

_____

Are shaker tube knife edges clearing structural steel?_____

Describe_____

Condition of support structure sound?_____

Describe_____

Signs of moisture or corrosion on walls?_____

Describe_____

Signs of moisture or corrosion on ceiling?_____

Describe_____

Shaker tubes in good condition?_____

Describe_____

Broken welds?_____

Describe_____

_____

_____

Comments for shaker level section:_____

_____

_____

_____

_____

8. SHAKER Compartment #_____

Cleaves pins in place?_____

Cotter keys and snap rings in place?_____

Inboard pillow block tight?_____

Outboard pillow block tight?_____

Motor quiet?_____

Belt tight?_____

Eccentric arm quiet?_____

Limit switch being made?_____

Sheave size:_____

Comments:_____

_____

9. DAMPER DRIVES Compartment #_____

	Deflation	Recirculation	Reinflation	Outlet
Operation?	_____	_____	_____	_____
Leaking?	_____	_____	_____	_____
Seating?	_____	_____	_____	_____

Comments:_____

_____

10. ASH HOPPERS Compartment #_____

Are hopper heaters operating properly?_____

Note defective heaters._____

Describe condition of hatches._____

_____

Comments:_____

_____

_____

DATE_____

COMP.	CLEVIS PINS COTTER KEYS SNAP RINGS	LIMIT SWITCH BEING MADE	OUTSIDE PILLOW BLOCK	INSIDE PILLOW BLOCK	MOTOR NOISE	LOOSE BELT	ECCENTRIC ARM
# 1							
# 3							
# 5							
# 7							
# 9							
#11							
#13							
# 2							
# 4							
#16							
#18							
#10							
#12							
#14							
#15							
#17							
#19							
#21							
#23							
#25							
#27							
#16							
#18							
#20							
#22							
#24							
#26							
#28							

G-GOOD
F-FAIR
P-POOR

INSPECTED BY_____

FIGURE 3. BAGHOUSE SHAKER INSPECTION

V. FABRIC STUDY

In the summer of 1979 the Harrington Unit 2 baghouse was rebagged with a variety of new fabrics with the intention of studying the flow and wear characteristics of the various bag types. The fabrics chosen for the study represented differing constructions, fabric weights, and coatings currently available. The test program called for

1. Periodic removal of sample bags for laboratory evaluation.
2. Keeping records on failure rates.
3. Regular physical inspection.
4. Pressure drop and relative flow measurements.

The fabrics employed in the study and their distribution in the Harrington baghouse are shown in Figure 4. The most interesting fabrics being studied are the Gore-tex and Nomex fabrics. Nomex, which has been known to rapidly fail in acid situations, has shown remarkable filtration and mechanical properties. The Gore-tex fabric is a unique material employing a highly different expanded Teflon membrane.

A. Fabric Wear

Immediately following the rebagging of the Harrington Unit 2 fabric filter system, a fabric evaluation program was initiated for the new fabrics. The purpose of this program was to evaluate the wear characteristics and throughput for each of the fabrics under test in the unit. Table I shows the fabrics being evaluated.

TABLE I. Test Fabrics

Criswell 442-57DC2	0.34 kg/m^2	(10 oz/yd^2)	10% Teflon coating
Criswell 449-57DC2	0.48 kg/m^2	(14 oz/yd^2)	10% Teflon coating
Criswell 449-I580	0.48 kg/m^2	(14 oz/yd^2)	Silicone/graphite/ Teflon coating
Criswell 449 COF	0.34 kg/m^2	(10 oz/yd^2)	Proprietary coating
Menardi Southern 601-T	0.34 kg/m^2	(10 oz/yd^2)	10% Teflon coating
Globe-Albany Allspun Nomex	0.19 kg/m^2	(5.5 oz/yd^2)	Permaguard coating

#2 BAGHOUSE WEST

1	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79	2	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79		
3	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79	4	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79		
5	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79	6	Company Menardi Southern Type 601-T Installed 6-15-79		
7	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79	8	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79		
9	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79	10	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79		
11	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79	12	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79		
13	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79	14	Company W.W. Criswell Type 442-57DC2 Installed 6-15-79		

#2 BAGHOUSE EAST

15	Company W.W. Criswell Type 442-57DC2 Installed 6-30-79	16	Company W.W. Criswell Type 449-580 14oz Installed 6-30-79 Burlington		
17	Company W.W. Criswell Type 442-57DC2 Installed 6-30-79	18	Company W.W. Criswell Type 449-580 Installed 6-30-79		
19	Company W.W. Criswell Type 449-57DC2 Installed 6-30-79 14 oz	20	Company Gore-Tex Type FF502AF-Gore-Tex Installed 11-79		
21	Company W.W. Criswell Type 442-57DC2 Installed 1-31-79	22	Company W.W. Criswell Type 449 COFII Installed 11-79		
23	Company W.W. Criswell Type 442-57DC2 Installed 4-8-80	24	Company Globe-Albany Type Nomex Installed 6-30-79		
25	Company W. W. Criswell Type 442-COF Installed 1-16-81	26	Company W.W. Criswell Type 449-COF Installed 6-30-79		
27	Company F.F. Type 504-1 TC Installed 1-8-81	28	Company W.W. Criswell Type 449-580 Installed 6-30-79		

Figure 4. Harrington Unit 2 Fabric Distribution

In order to examine the various fabrics for wear, samples were removed from each of the test compartments on a periodic basis and sent to Environmental Consultants, Inc., for evaluation (see the appendix for testing reports). Each sample was subjected to the following tests:

1. Breaking strength.
2. Mullen Burst.
3. MIT Flex -0.08 cm (0.03-in.) jaw @ 1.8 kg (4 lb).
4. Loss on ignition @ 650°C (1200°F).
5. Permeability.

According to the testing program conducted by Environmental Consultants for SPS, the weakened area along the most severe fold lines were the ones to be tested for mechanical strength rather than the stronger areas away from the fold lines. SPS believes that testing results obtained in this manner are more representative of the rate of decay in mechanical properties for a material since it will be the weakened areas that will determine the fabric life.

The results of Mullen Burst and breaking strength testing for each of the fabrics are shown in Figures 5 and 6. The 0.48 kg/m^2 (14 oz/yd^2) materials show much higher initial values for both Mullen Burst and breaking strength than the 0.34 kg/m^2 (10 oz/yd^2) fabrics, yet the rate of decay of these values is seen to be much higher. The higher initial values are due to the stronger fill yarn construction of the heavier fabrics while the difference in the rate of decline of the Mullen Burst and breaking strength is due to the different reaction of the fabrics to the baghouse environment and wear during the cleaning process.

On both plots, the highest initial values are for the proprietary Cris-O-Flex (COF) coated material. This is due to the fact that the fabric was not heat-cleaned prior to application of the coating. Since heat cleaning weakens the fabric to some extent, the COF-finished material has the initial advantage. This advantage is seen to decline, however, as all three of the 0.48 kg/m^2 (14 oz/yd^2) materials appear to have similar Mullen Burst values after a year in service.

Nomex, the only synthetic fabric in service, is shown on each of the plots. This synthetic material, having inferior tensile properties to glass,

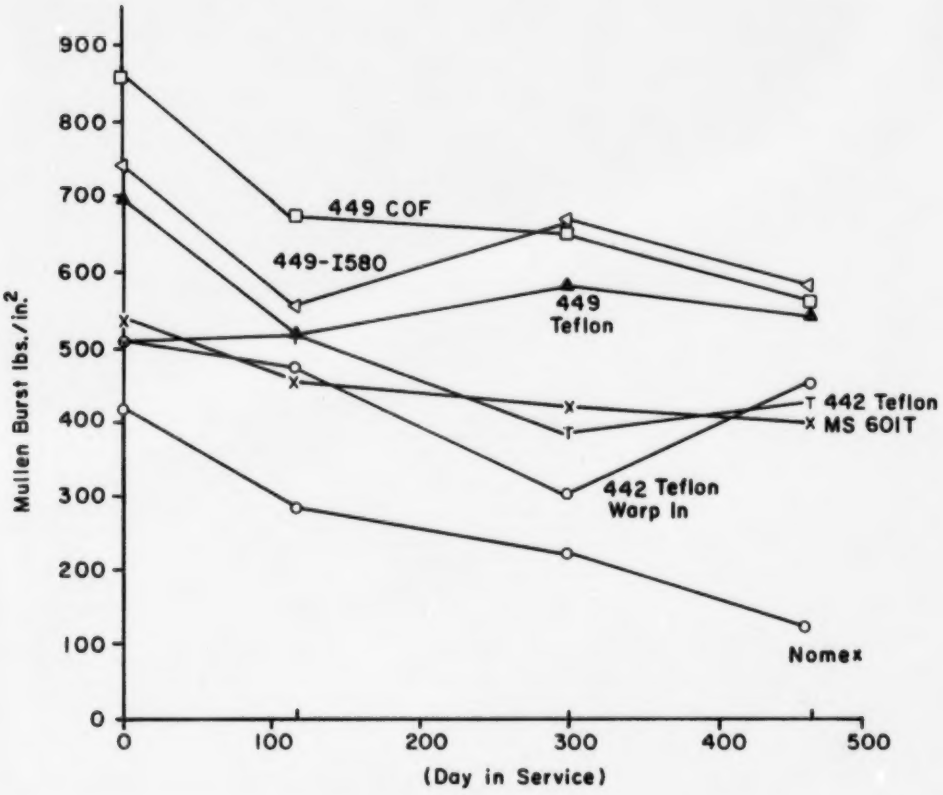

Figure 5. Mullen Burst

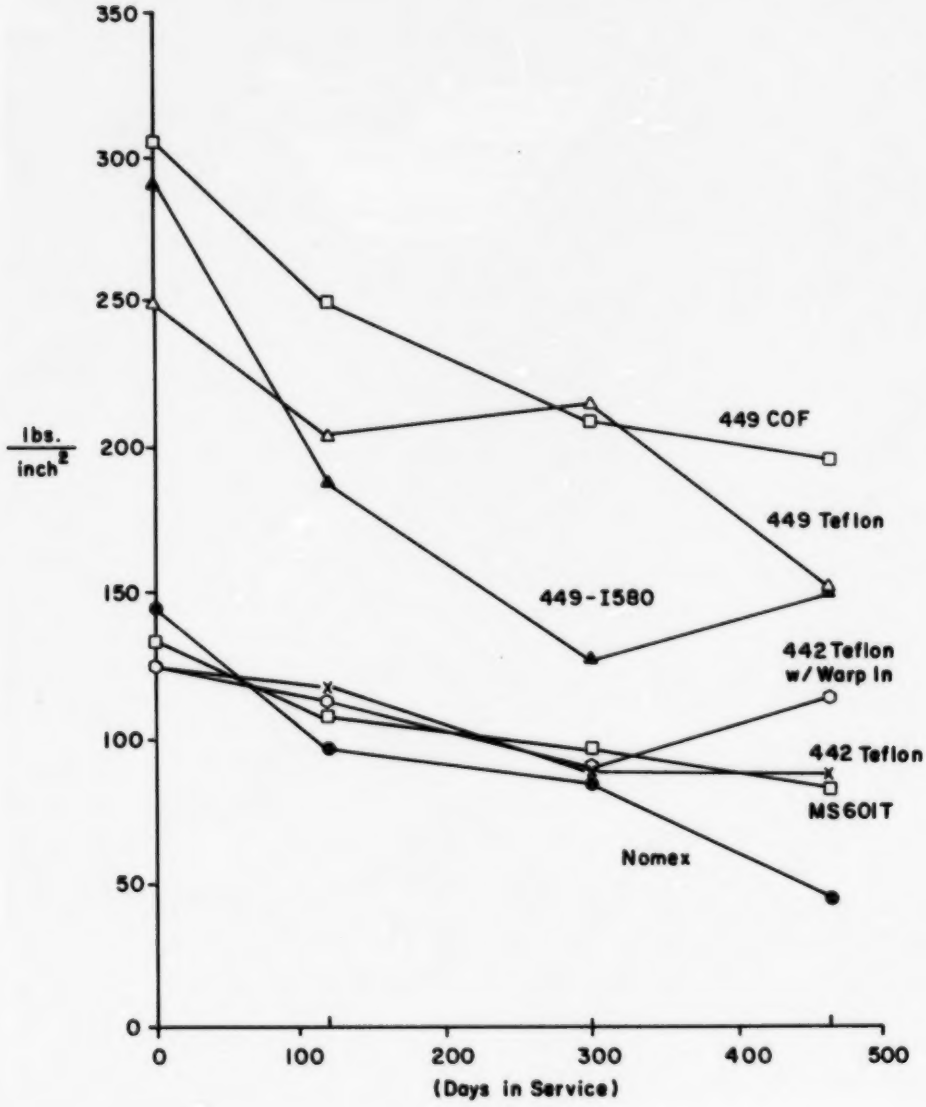

Figure 6. Breaking Strength

nevertheless excells in the critical area of flex strength.

Aside from showing some different characteristics of fabrics of different weight, the Mullen Burst and breaking strength plots are disappointing in that there is nothing in the appearance of these curves to indicate that two of the test fabrics have reached termination of their useful life. The only indication of incipient failure obtained from the fabric testing results is shown on the MIT Flex plot in Figure 7. Here the reduced MIT value (MIT Flex/Initial MIT Flex, M/M_o) is plotted vs. service life. An indication of incipient failure is obtained by looking at the steep slope and low values for M/M_o for the 449 COF and 449-I580 fabrics. Both these fabrics are scheduled to be replaced due to the high failure rate at Harrington. That the MIT Flex tests should correlate best with the progress of fabric wear is certainly understandable since, of all the testing methods, the MIT Flex most accurately duplicates what the fabric undergoes during cleaning.

The existence of a critical value for M/M_o can be inferred from the simultaneous failure of the two fabrics as they approach the same reduced MIT Flex value (0.07). If such a critical value exists at which termination of fabric life can be determined, it should become evident as the remainder of the test fabrics fail.

The data for Nomex is shown on the reduced MIT Flex plot but is not directly comparable to the glass fabrics since the test conditions were not the same. The MIT values for Nomex were obtained with a 2.3 kg (5 lb) weight instead of the usual 1.81 kg (4 lb) weight used for glass in order to generate numbers in a reasonable amount of time. The Nomex data is interpreted such that the fabric appears to yield acceptable remaining life and is in no way inferior to the glass materials. A paper titled "SPS Experience With Fabric Filtration" presents a more detailed discussion of the correlation between fabric testing results and actual operating conditions (1).

B. Failures by Compartmental Position

Any given section of bags within a compartment would be expected to

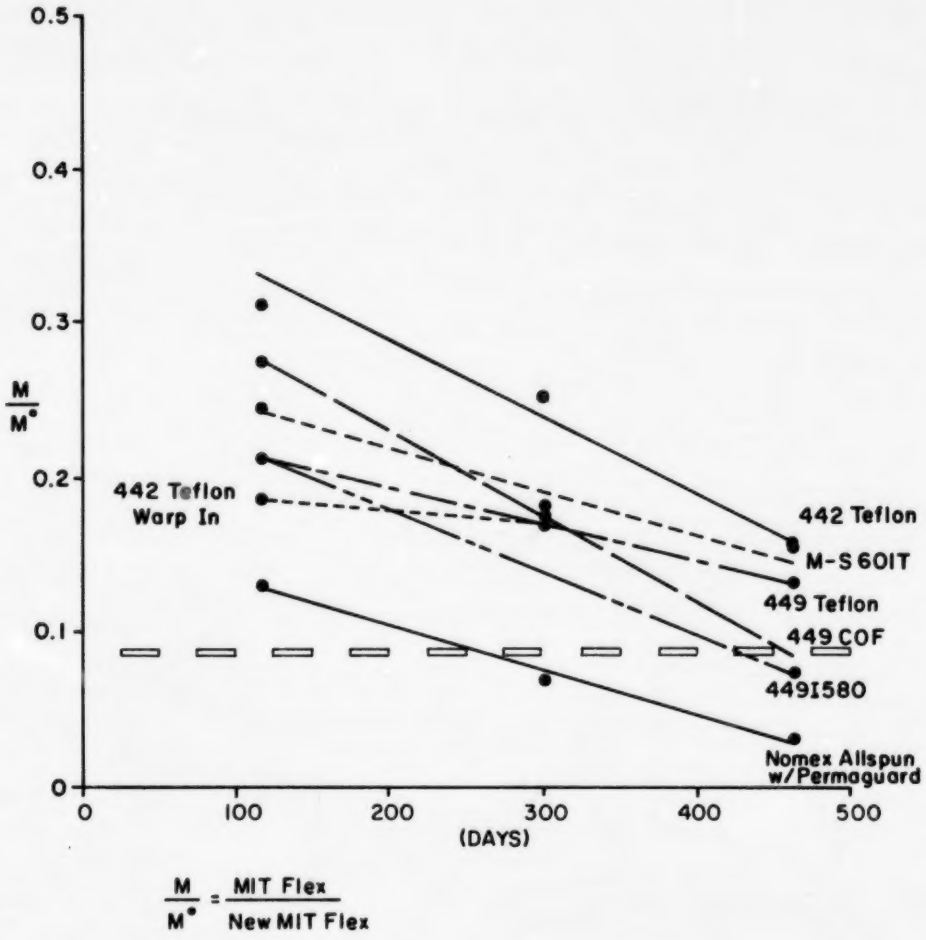

Figure 7. Reduced MIT Flex Vs. Time

have roughly the same failure rate as any other section of bags, all things being equal. In the case where bag failures are not equally distributed throughout a compartment, the cause of higher failure rates should be identified and eliminated, if possible, to save costly bag replacements and to allow faulty design concepts to be corrected.

To analyze the failure rate by compartment position at Harrington Station, the failures that have occurred to date have been superimposed onto a single plot by thimble position as shown in Figure 8. Two types of failures have been noted. Any small hole in a fabric is referred to as a "pinhole;" whereas, a large section ripped out of the fabric is shown as a "blowout."

The pinhole type failure is by far less prevalent now than during the first year of operation where it was the main failure type with the original fabric. These initial failures were thought to be due to fabric stretching resulting in a lack of tension and blousing over the thimble. The data indicate that there is no discernible pattern to the pinhole type of failure. Therefore, in Figure 8, only the blowout location is shown. The blowout failures definitely appear to occur more often in certain locations. The outside two rows account for 73 percent of all the blowout failures. Calculating the failures per thimble position for the outside two rows yields 0.91 failures per thimble vs. an overall average of 0.39.

Narrowing the failure area to the four corner areas two bags deep and five bags wide yields the failure rate shown in Figure 8. The two areas adjacent to the interior wall are seen to have the greatest failure rates with 1.8 and 1.2 failures per thimble compared to 0.21 for thimbles not in the corner areas. The corner areas adjacent to the outside walls also show significantly higher failure rates with 0.8 and 0.7 failures per thimble position. Factors contributing to these higher failure rates are thought to be hopper shed plate design and turbulent flow distribution in the ash hopper.

C. Failure Mechanisms in Filtration Fabrics

The two fabric styles undergoing premature failure at Harrington, Criswell's 449 COF and 449-I580, appear to be experiencing a wear pattern

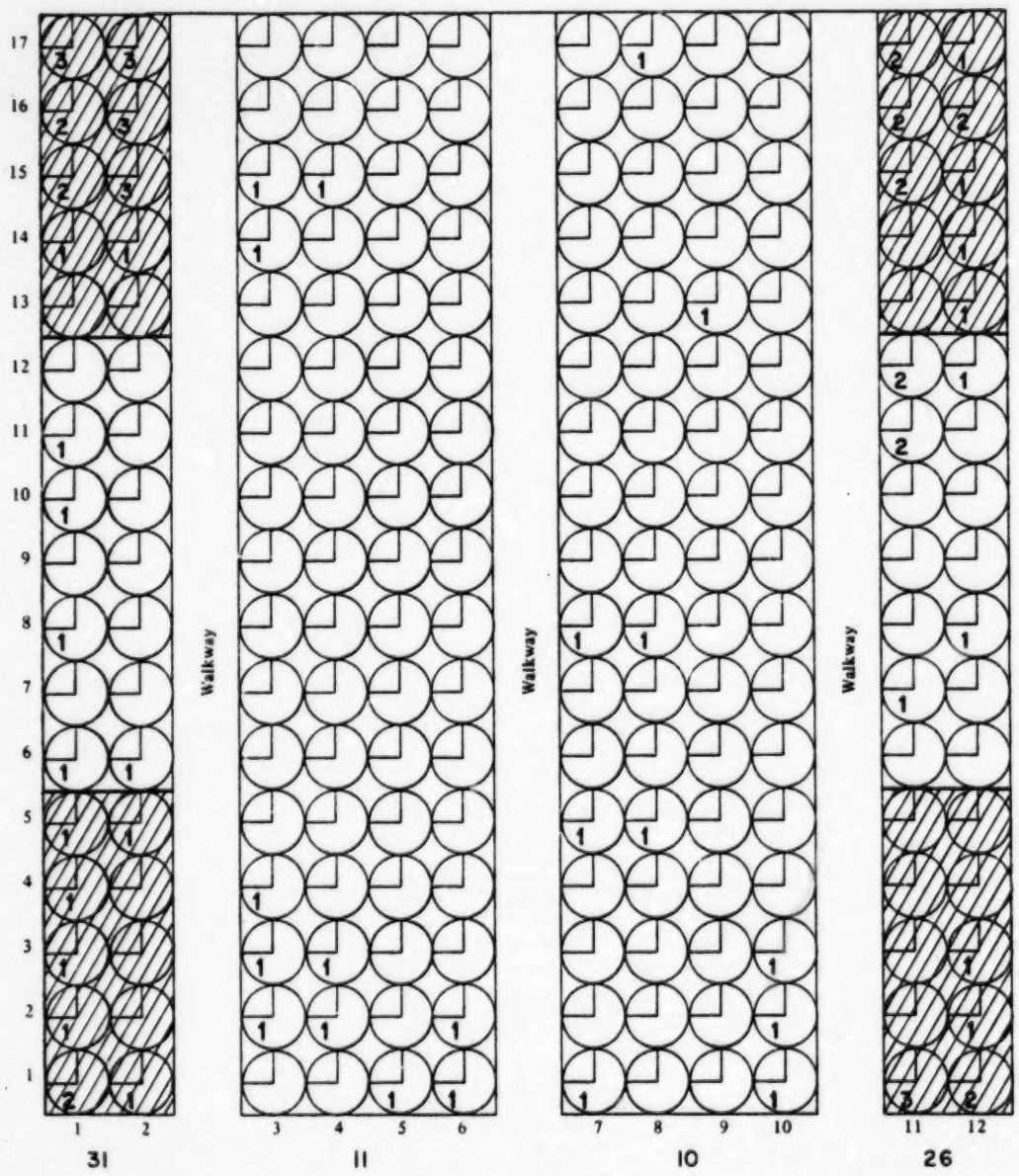

Figure 8. Failures By Thimble Position

that is typical of the other fabrics being tested except that these two fabrics are damaged to a much greater degree. The typical wear pattern consists of a severely abraded area along a fold line in the fabric originating at the top and proceeding down the fabric approximately one-third the length of the bag. Along these abraded fold lines (called "wooley worms") pinhole failures occur at irregular spacings. A single bag may have as few as two such lines or as many as six. Eventually, failure will occur in the 0.48 kg/m^2 (14 oz/yd^2) fabrics of these "wooley worms" as a vertical split up to several meters (feet) long. The lighter, Teflon coated fabrics, however, most often exhibit a rectangular-shaped blowout where the fabric appears to have had a section of cloth cut out of it. This behavior is believed to be due to the weaker warp yarn construction of the 0.34 kg/m^2 (10 oz/yd^2) material.

To have a closer look at a "wooley worm" failure, one of the affected fabrics was removed from the baghouse and dissected. The fabric chosen was one that had a vertical split along a fold line where massive fiber damage along the fold lines had occurred. It is not uncommon for two such areas to be very close to one another, suggesting that the fabric was actually folding back on itself and undergoing abrasion.

The deflation process is expected to play only a minor role in the development of the "wooley worm" type failure observed at Harrington since the deflation levels employed are very low (approximately 0.5 cm (0.2 in.) w.g.) and observation shows no discernible flexing of the material. In order to examine the effect of shaking on the fabric, one compartment of an EPA-sponsored pilot baghouse currently in operation at Harrington was rebagged with one new Criswell 449-I580 0.48 kg/m^2 (14 oz/yd^2) graphite/Teflon/silicone (G/T/S) coating and one Criswell 442-57DC2 0.34 kg/m^2 (10 oz/yd^2) Teflon- coated. The other thimbles were left unbagged to allow for better observation. The effect of the shaking forces on these fabrics was then viewed by entering the compartment at both the upper and lower levels. The motions of the fabric were complex; however, it was clearly apparent that the shaking forces were responsible for causing folding and flexing along certain lines in the fabric.

The two fabrics appeared to have somewhat different reactions to the

shaking forces. The 0.34 kg/m^2 (10-oz/yd^2), Teflon-coated material seemed to transmit the intensity of shake farther down the fabric than the 0.48- kg/ m^2 (14-oz/yd^2) material. By comparison, the heavier fabric reacted to the same shaking forces in a more sluggish manner than the lighter material. The 0.34-kg/m^2 (10-oz/yd^2) Teflon-coated fabric appeared to have a very "live" reaction to shaking. The degree to which flexing occurred in the cloth was also different for the two fabrics. The relatively limp 14-oz. material appeared to be undergoing a more severe folding action while the rigid Teflon-coated fabric tended to resist the folding forces.

It is felt that this difference in reaction to the shaking forces may play the principal role in the premature failure of the 449 fabrics installed at Harrington Station. The more rigid Teflon coating may be protecting the fabric by mechanically restricting its motion during the cleaning cycle. The reaction of fabric to the forces employed during cleaning is undoubtedly one of the most important factors in determining fabric life. Further studies of this type are planned for the pilot unit in order to better define the reaction of various fabrics to shaking forces and its relation to fabric wear.

D. Reducing Fabric Wear

After an appreciation has been developed for the mechanisms involved in fabric wear, the next logical step is to attempt to minimize these actions by some means. One method of reducing the severity of the folding and flexing wear occurring during the shaking process that appears to hold promise is that of employing smaller shake amplitude by replacing the existing eccentric with one having less of a throw. The intention of such a change is that the fabric would undergo less severe flexing; however, if this is the only change made, cleaning will suffer as more dust cake will be left on the fabric. Dennis (2) has shown that dust removal is a linear function of the acceleration applied to a fabric. The acceleration, a, imparted to a fabric during shaking is proportional to Af^2 where A is the amplitude and f is the frequency. Dennis gives the equation

$$a = 4\pi^2 kAf^2 \qquad (1)$$

where $k = 0.7$.

The ratio of acceleration compared to some standard values for A and f on a given system can be calculated from

(acceleration ratio) $$\frac{a}{a_s} = \frac{Af^2}{A_s f_s^2} = \frac{\lambda d^2}{\lambda_s d^2_s} \qquad (2)$$

where

d = sheave diameter
λ = eccentric throw

If, for example, the fabric was being shaken by a mechanism employing a 13.5-cm (5.3-in.) drive pulley and a 1.3-cm (1/2-in.) throw eccentric and a change of eccentric is accomplished to one with a 1 cm (3/8-in.) throw, then the acceleration would be only 75 percent of its former value.

A study was undertaken at Harrington to determine the impact of amplitude and frequency changes on cleaning by placing different sizes of eccentrics and shaker motor pulleys (sheaves) on several compartments and measuring the change in flow through the compartment with manometers installed across the outlet dampers.

The relative flow after cleaning vs. the acceleration ratio plot is shown in Figure 9. The plot confirms the results reported by Dennis in that a directly proportional measure of dust removal, throughput after cleaning, is linearly related to the acceleration imparted to the fabric during shaking.

From Figure 9 it is apparent, then, that reducing the eccentric throw from 1.3 cm (1/2-in.) to 1 cm (3/8-in.) would cause an unacceptable lowering of flow through a compartment if no other changes were made. However, as can also be seen from the plot, the installation of a 15.2-cm (6-in.) pulley brings the acceleration ratio back close to 1.0 and the flow comes back to the same level as under the original conditions. Therefore, increasing sheave size can be used in conjunction with smaller shake amplitudes without incurring unacceptable losses in cleaning. In light of this, studies are now

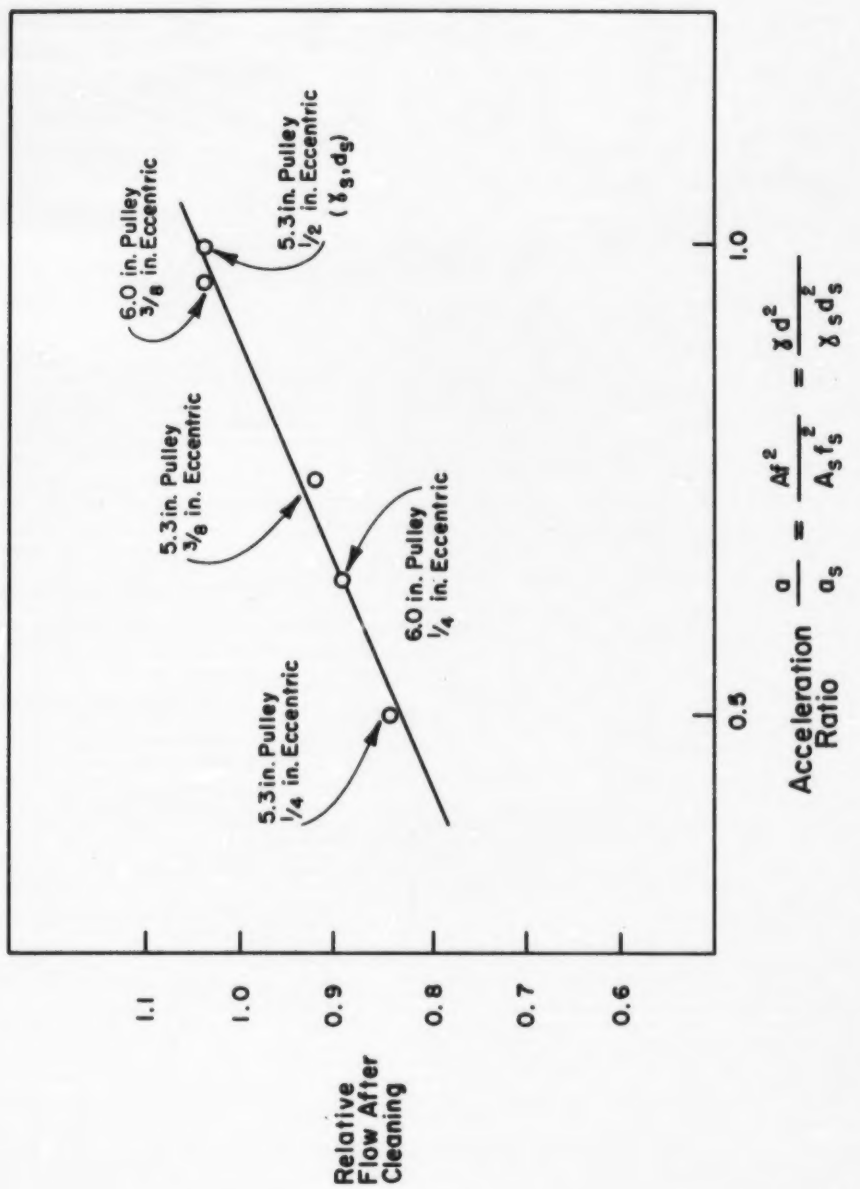

Figure 9. Effects of Various Sheave and Eccentric Sizes on Cleaning

underway to determine the effect on fabric wear of employing 1-cm (3/8-in.) eccentrics and 15.2-cm (6-in.) shaker motor pulleys instead of the 13.5-cm (5.3-in.) pulleys and 1.3-cm (1/2-in.) eccentrics currently being used.

The results of fabric filtration analyses are now beginning to reveal performance trends for various types of fabrics. In the coming months, SPS plans to look at dust and flow distribution by analyzing individual compartment pressure drop behavior. SPS hopes to make more compartment observations and conduct individual compartment throughput measurements. In addition, SPS will continue to evaluate different fabrics, including two entire compartments of 0.34 kg/m^2 (10 oz/yd^2) Acid Flex coated bags and one compartment of 0.19 kg (5.5 oz/yd^2) Nomex bags.

VII. REFERENCES

1. Chambers, R. L., Ladd, K. L., and Kunka, S. L., "SPS Experience With Fabric Filtration," presented at 5th International Fabric Filter Forum, Phoenix, Arizona, January 1981.

2. Dennis, R.C., Cass, R.W., Cooper, D.W., Hall, R.R., Hampl, V., Klemm, H.A., Langley, J.E., and Stern, R.W., GCA Corporation. "Filtration Model for Coal Fly Ash With Glass Fabrics," EPA-600/7-77-084 (NTIS No. PB 276 489), August 1977.

APPENDIX

Fabric Testing Reports

ENVIRONMENTAL CONSULTANT
COMPANY

A Division of E. C. C., Inc.

December 1, 1980
TLN 1766
Page 1

R E P O R T

SOUTHWESTERN PUBLIC SERVICE COMPANY

REFERENCE: HARRINGTON 2 - BAG FAILURES

Four filter bags were submitted for testing and evaluation for the mechanism of fabric failure.

The filter bags were labeled as follows:

4 (6,8)
6 (6,10)
13 (7,4)
16 (12,16)

Attached are the results of the testing data.

The as received weights and air flow characteristics of the bags in general, are comparable in weights and comparable in air flow characteristics to other previously tested bags. The air flows on bag 16 were higher in the as received condition than bags 4, 6, and 13. The as received weights were also lower in dust retention as a percentage of original fabric weight with about 50% added weight compared to about 85% added weight of the other three fabrics.

All filter bags were received with hole formations evident.

16 (12,16)

This filter bag had three distinct lines of flex caused by the collapse and abrasion configuration during the on line and cleaning cycles. There were two other flex or wear lines noted, however these areas indicated by 3 and 4 on PHOTO A were very minor flex areas. Lines 1, 2 and 5 were very significant flex abrasion positions and ran vertically the entire length of the bag.

ENVIRONMENTAL CONSULTANT COMPANY
P. O. Box 9936
Phoenix, Arizona 85068

PREPARED FOR SOUTHWESTERN PUBLIC SERVICE COMPANY

DATE DECEMBER 1, 1980
TLN 1766
PAGE 8

Identification		16 (12/16)	TOP	CENTER	BOTTOM	FLEX LINE
Fiber Content			GLASS			
Weight	As received		20.01	20.83	21.74	
Oz/sq. yd.	Cleaned (Vacuum)		15.52	15.47	15.12	
	Cleaned (Washed)		13.35	13.38	13.37	
Thickness (inches)			.018			
Count			44X24	44X24	44X24	
Weave			3X1 TW			
Yarn	Warp/Length		37 1/0			
System	Filing/Width	2 TEXT/1 FIL	75 1/2 F/T			
Permeability	As received		2.10	2.15	1.87	
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		12.13	11.98	13.03	
	Cleaned (Washed)		54.8	55.6	55.5	
Breaking	Warp/Length		461	453	456	
Strength lbs/inch	Filling/Width		121	129	126	21 - 38
Breaking	Warp/Length	@ 550	16.18%	17.64%	17.09%	-
Strength % Loss	Filling/Width	@ 250	51.60%	44.40%	45.60%	91.6%-84.8%
Mullen Burst (lbs/sq inch)			658	643	664	101 - 185
Mullen Burst % Loss		@ 650	0%	1.08%	0%	84.5%-71.5%
Flex Cycles (MIT Method)	Warp		2,483	2,718	2,568	-
.03 JAW @ 4 LBS	Fill		474	531	648	14 - 36
Flex Cycles (% Loss)	Warp	@ 5,900	57.91%	53.93%	56.47%	-
.03 JAW @ 4 LBS	Fill	@ 1,900	75.05%	72.05%	65.89%	99+%
% Extractable	Solvent					
Matter	Water					
Acid/Alkaline (PH)						
% Ignition Loss (LOI)		SEAM AREA @ 1200°F	1.87%			
Treatment Physical Type			NONE			
Treatment Chemical Type			G/T/S			
% Elongation	Warp/Length					
% Shrinkage	Filling/Width					
Fabrication	Seaming	TRIPLE ROW	CHAIN			
	Cuffing		LOCK			
	Ring Cover					
Hardware Type			NONE			
Length (inches) Tension _____						
Diameter (inches) Tension _____						
Fabrication Rating						
Other Testing	SEAM REGISTRATION (INCHES)		0.68			

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DATE DECEMBER 1, 1980
FLN 1766
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Identification		13 (7/A)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight Oz/sq. yd.	As received		18.07	18.46	18.98
	Cleaned (Vacuum)		14.13	13.69	13.93
	Cleaned (Washed)		9.99	10.13	10.06
Thickness (inches)			.017		
Count			55X30	55X31	55X30
Weave			3X1 TW		
Yarn System	Warp/Length		150 1/2 F		
	Filing/Width		150 2/2 T		
Permeability CFM/sq ft @ .5" H_2O	As received		1.50	1.47	1.38
	Cleaned (Vacuum)		14.8	15.2	15.1
	Cleaned (Washed)		54.3	52.6	52.4
Breaking Strength lbs/inch	Warp/Length		183	198	193
	Filling/Width		105	109	107
Breaking Strength % Loss	Warp/Length	@ 250	26.80%	20.80%	22.80%
	Filling/Width	@ 130	19.23%	16.15%	17.69%
Mullen Burst (lbs/sq inch)			404	438	450
Mullen Burst % Loss		@ 525	23.05%	16.57%	14.28%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		4,687	5,618	5,172
	Fill		101	94	132
Flex Cycles (% Loss) .03 JAW @ 4 LBS	Warp	@ 15,000	68.75%	62.55%	65.52%
	Fill	@ 500	79.80%	81.20%	73.60%
% Extractable Matter	Solvent				
	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		SEAM AREA @ 1200°F	8.23%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming		CHAIN		
	Cuffing		LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension _____					
Diameter (inches) Tension _____					
Fabrication Rating					
Other Testing		SEAM REGISTRATION (INCHES)	0.87		

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PREPARED FOR SOUTHWESTERN PUBLIC SERVICE COMPANY DATE DECEMBER 1, 1980
TLN 1766
PAGE 6

Identification		6 (6/10)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight	As received		18.21	18.47	18.23
Oz/sq. yd.	Cleaned (Vacuum)		13.74	13.83	13.29
	Cleaned (Washed)		10.00	9.98	9.99
Thickness (inches)			.017		
Count			55X30	55X29	55X30
Weave			3X1 TW		
Yarn	Warp/Length		150 1/2 F		
System	Filing/Width		150 1/4 T		
Permeability	As received		1.68	1.61	1.67
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		19.2	19.2	22.0
	Cleaned (Washed)		50.9	48.9	49.4
Breaking	Warp/Length		184	193	187
Strength lbs./inch	Filling/Width		73	69	72
Breaking	Warp/Length	@ 250	26.40%	22.80%	25.20%
Strength % Loss	Filling/Width	@ 130	43.85%	46.92%	44.62%
Mullen Burst (lbs/sq inch)			403	418	412
Mullen Burst % Loss		@ 525	23.24%	26.38%	21.52%
Flex Cycles (MIT Method)	Warp		5,187	4,961	4,535
.03 JAW @ 4 LBS	Fill		91	74	77
Flex Cycles (% Loss)	Warp	@ 15,000	65.42%	66.92%	69.76%
.03 JAW @ 4 LBS	Fill	@ 500	81.80%	85.20%	84.60%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		SEAM AREA @ 1200°F	9.84%	10.9	
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
	Seaming		CHAIN		
Fabrication	Cuffing		LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing		SEAM REGISTRATION (INCHES)	0.43		

ENVIRONMENTAL CONSULTANT
COMPANY
P. O. Box 9936
Phoenix, Arizona 85068

PREPARED FOR SOUTHWESTERN PUBLIC SERVICE COMPANY
HARRINGTON STATION 2

DATE DECEMBER 1, 1980
TLN 1766
PAGE 5

Identification		4 (6/8)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight	As received		18.82	19.06	18.83
Oz/sq. yd.	Cleaned (Vacuum)		13.78	13.57	13.64
	Cleaned (Washed)		10.01	9.98	9.99
Thickness (inches)			.017		
Count			55X30		
Weave			3X1 TW		
Yarn	Warp/Length		150 1/2 F		
System	Filing/Width		150 2/2 T		
Permeability	As received		1.83	1.81	1.57
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		18.9	19.3	19.4
	Cleaned (Washed)		48.3	50.1	49.9
Breaking	Warp/Length		194	190	203
Strength lbs/inch	Filling/Width		94	113	109
Breaking	Warp/Length	@ 250	22.40%	24.00%	18.80%
Strength % Loss	Filling/Width	@ 130	27.69%	13.08%	16.15%
Mullen Burst (lbs/sq inch)			431	456	452
Mullen Burst % Loss		@ 525	17.90%	13.43%	13.90%
Flex Cycles (MIT Method)	Warp		5,873	6,187	6,002
.03 JAW @ 4 LBS	Fill		112	109	124
Flex Cycles (% Loss)	Warp	@ 15,000	60.85%	58.75%	59.99%
.03 JAW @ 4 LBS	Fill	@ 500	77.60%	78.20%	75.20%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		SEAM AREA @ 1200°F	8.09%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming		CHAIN		
	Cuffing		LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing		SEAM REGISTRATION **(INCHES)	0.73		

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R E P O R T

SOUTHWESTERN PUBLIC SERVICE COMPANY

REFERENCE: HARRINGTON 2 BAGHOUSE

Eighteen used filter bags were submitted from the Wheelabrator shaker system for testing and evaluation.

The bags were tagged as follows:

COMPARTMENT	POSITION	COMPARTMENT	POSITION
2	1,10	4	5,9
6	6,9	7	5,9
8	6,9	9	5,8
10	5,10	18	8,9
19	5,10	20	5,10
21	5,10	21	5,10
22	5,11	22	8,11
24	8,16	25	8,9
26	8,11	26	9,11

Attached are the results of the testing data.

In general, all submitted bags have generally three to four flex lines. The Teflon B finished bags however, had far less severe flex lines in most cases, with a lower fiber breakage level.

Teflon B coated bags from 2 (1,10); 7 (5,9) and 8 (6,9) had hole formations developed on the flex line, however, restricted to one general area. The severe abrasion did not continue above or below these hole fomrations. It appears that the hole formation was due to both a horizontal fold in conjunction with a vertical fold rather than a vertical only fold. This condition may be present in the original bag, perhaps due to the packaging methods.

Samples of these three bags are being returned for your observations.

All other Teflon B tested bags do not have severe flex fold lines of significant wear with a lower loss of MIT flex folding endurances. These bags have a projected continued life span of at least an additional 25% plus or about 4 to 5 months, based on 18 months to date.

Bag 20 (5,10) was a Gore Tex laminate to glass fabric. The MIT endurance levels were very good due to the non penetration of the particulate beyond the Gore membrane into the fiber glass yarns. Nearly all of the membrane was intact, with minimal flex areas where the membrane had broken.

Bag 22 (5,11) achieved rather low % loss figures on MIT and correspondingly high strength values. It is believed that the bag has not been exposed for the 18 month duration. Bag 22 (8,11) was also found to be in good condition.

Both fabrics from 26 (8,11) and 26 (9,11) were in a severe state of flex fatigue, with very low levels of remaining flex endurance existing on the flex lines.

Bag 24 (8,16) acid resistant treated Nomex is continuing to decline in physical testing results. The present level of endurance is very low in both flex levels in the warp and length positions. The bag does not have distinct flex abrasion lines with the weakened condition generally overall the bag surface. The cuff material which is void from the filtration operation is also degraded, however, at a slightly lower level than the body of the filter bag.

Several bag samples are being returned under separate cover demonstrating the various findings.

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Identification		2 (1,10)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight	As received		21.16	21.07	20.83
Oz/sq. yd.	Cleaned (Vacuum)		13.46	13.41	13.37
	Cleaned (Washed)		10.23	10.23	10.21
Thickness (inches)			.016		
Count			55X30	55X30	55X30
Weave			3X1 TW		
Yarn	Warp/Length		150 1/2 F		
System	Filing/Width		150 2/2 T		
Permeability	As received		1.49	1.53	1.55
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		21.4	21.8	22.2
	Cleaned (Washed)		63.1	62.4	62.3
Breaking	Warp/Length		164	170	178
Strength lbs/inch	Filling/Width		73	71	95
Breaking	Warp/Length	@ 250	34.40%	32.00%	28.80%
Strength % Loss	Filling/Width	@ 130	43.85%	45.38%	26.92%
Mullen Burst (lbs/sq inch)			302	286	394
Mullen Burst % Loss		@ 525	42.48%	45.52%	24.95%
Flex Cycles (MIT Method)	Warp		2184	1993	2407
.03 JAW @ 4 LBS	Fill		47	39	69
Flex Cycles (% Loss)	Warp	@ 15,000	85.44%	86.71%	83.95%
	Fill	@ 500	90.60%	92.20%	86.20%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	8.93%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE	CHAIN		
	Cuffing	DOUBLE	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing					

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Identification			4 (5,9)	TOP	CENTER	BOTTOM
Fiber Content				GLASS		
Weight Oz/sq. yd.	As received			19.93	20.18	20.42
	Cleaned (Vacuum)			13.26	13.19	13.20
	Cleaned (Washed)			10.28	10.29	10.29
Thickness (inches)				.016		
Count				55X29	55X30	55X30
Weave				3X1 TW		
Yarn System	Warp/Length			150 1/2 F		
	Filing/Width			150 2/2 T		
Permeability CFM/sq ft @ .5" H_2O	As received			1.61	1.63	1.54
	Cleaned (Vacuum)			22.8	23.6	22.8
	Cleaned (Washed)			60.4	59.8	59.9
Breaking Strength lbs/inch	Warp/Length			184	199	214
	Filling/Width			101	93	112
Breaking Strength % Loss	Warp/Length	@	250	26.40%	20.40%	14.40%
	Filling/Width	@	130	22.31%	28.46%	
Mullen Burst (lbs/sq inch)				423	425	507
Mullen Burst % Loss		@	525	19.43%	19.05%	80.11%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp			2,403	2,761	2,983
	Fill			88	76	103
Flex Cycles (% Loss) .03 JAW @ 4 LBS	Warp	@	15,000	83.98%	81.59%	80.11%
	Fill	@	500	82.40%	84.80%	79.40%
% Extractable Matter	Solvent					
	Water					
Acid/Alkaline (PH)						
% Ignition Loss (LOI)		@	1200°F (SEAM AREA)	8.84%		
Treatment Physical Type				NONE		
Treatment Chemical Type				TEFLON B		
% Elongation	Warp/Length					
% Shrinkage	Filling/Width					
Fabrication	Seaming		TRIPLE ROW	CHAIN		
	Cuffing		DOUBLE ROW	LOCK		
	Ring Cover					
Hardware Type				NONE		
Length (inches) Tension _____						
Diameter (inches) Tension _____						
Fabrication Rating						
Other Testing						

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Identification			6 (6,9)	TOP	CENTER	BOTTOM
Fiber Content				GLASS		
Weight Oz/sq. yd.	As received			19.27	19.43	19.34
	Cleaned (Vacuum)			13.32	13.18	13.24
	Cleaned (Washed)			10.30	10.30	10.29
Thickness (inches)				.017		
Count				55X30	55X30	55X29
Weave				3X1 TW		
Yarn System	Warp/Length			75 1/2 F		
	Filing/Width			150 1/4 T		
Permeability CFM/sq ft @ .5" H_2O	As received			1.81	1.78	1.82
	Cleaned (Vacuum)			19.3	19.9	21.1
	Cleaned (Washed)			61.9	62.4	60.9
Breaking Strength lbs/inch	Warp/Length			187	183	184
	Filling/Width			101	99	98
Breaking Strength % Loss	Warp/Length	@	250	25.20%	26.80%	26.40%
	Filling/Width	@	130	22.31%	23.85%	24.62%
Mullen Burst (lbs/sq inch)				368	361	364
Mullen Burst % Loss		@	525	29.90%	31.23%	30.67%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp			2,162	2,089	2,247
	Fill			81	100	83
Flex Cycles (% Loss) .03 JAW @ 4 LBS	Warp	@	15,000	85.59%	86.07%	85.02%
	Fill	@	500	83.80%	80.00%	83.40%
% Extractable Matter	Solvent					
	Water					
Acid/Alkaline (PH)						
% Ignition Loss (LOI)		@	1200°F (SEAM AREA)	9.97%		
Treatment Physical Type				NONE		
Treatment Chemical Type				TEFLON B		
% Elongation	Warp/Length					
% Shrinkage	Filling/Width					
Fabrication	Seaming		DOUBLE ROW	CHAIN		
	Cuffing		SINGLE ROW	LOCK		
	Ring Cover					
Hardware Type						
Length (inches) Tension _____						
Diameter (inches) Tension _____						
Fabrication Rating						
Other Testing						

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Identification			7 (5,9)	TOP	CENTER	BOTTOM
Fiber Content				GLASS		
Weight	As received			19.65	19.64	19.83
Oz/sq. yd.	Cleaned (Vacuum)			13.52	13.46	13.21
	Cleaned (Washed)			10.24	10.26	10.26
Thickness (inches)				.017		
Count				54X30	55X29	55X29
Weave				3X1 TW		
Yarn	Warp/Length			150 1/2 F		
System	Filing/Width			150 2/2 T		
Permeability	As received			1.68	1.74	1.69
CFM/sq ft @ .5" H_20	Cleaned (Vacuum)			20.2	20.2	21.0
	Cleaned (Washed)			61.3	64.2	63.5
Breaking	Warp/Length			164	167	182
Strength lbs/inch	Filling/Width			72	78	99
Breaking	Warp/Length		@ 250	34.40%	33.20%	27.20%
Strength % Loss	Filling/Width		@ 130	44.62%	40.00%	23.85%
Mullen Burst (lbs/sq inch)				234	231	393
Mullen Burst % Loss			@ 525	55.43%	56.00%	25.14%
Flex Cycles (MIT Method)	Warp			1,861	1.657	1,993
.03 JAW @ 4 LBS	Fill			34	31	93
Flex Cycles (% Loss)	Warp		@ 15,000	87.59%	88.95%	86.71%
.03 JAW @ 4 LBS	Fill		@ 500	93.20%	93.80%	81.40%
% Extractable	Solvent					
Matter	Water					
Acid/Alkaline (PH)						
% Ignition Loss (LOI)			@ 1200°F (SEAM AREA)	9.10%		
Treatment Physical Type				NONE		
Treatment Chemical Type				TEFLON B		
% Elongation	Warp/Length					
% Shrinkage	Filling/Width					
Fabrication	Seaming		TRIPLE ROW	CHAIN		
	Cuffing		DOUBLE ROW	LOCK		
	Ring Cover					
Hardware Type						
Length (inches) Tension						
Diameter (inches) Tension						
Fabrication Rating						
Other Testing						

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			TOP	CENTER	BOTTOM
Identification		9 (5,8)			
Fiber Content			GLASS		
Weight	As received		19.83	19.91	20.27
Oz/sq. yd.	Cleaned (Vacuum)		12.74	12.98	13.06
	Cleaned (Washed)		10.13	10.09	10.11
Thickness (inches)			.016		
Count			55X30	55X30	55X30
Weave			3X1 TW		
Yarn	Warp/Length		150 1/2 F		
System	Filing/Width		150 2/2 T		
Permeability	As received		1.99	2.04	1.71
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		30.7	29.3	28.4
	Cleaned (Washed)		52.8	51.6	51.9
Breaking	Warp/Length		188	189	193
Strength lbs/inch	Filling/Width		94	114	113
Breaking	Warp/Length	@ 250	24.80%	24.40%	22.80%
Strength % Loss	Filling/Width	@ 130	27.69%	12.31%	13.08%
Mullen Burst (lbs/sq inch)			403	426	469
Mullen Burst % Loss		@ 525	23.24%	18.86%	10.67%
Flex Cycles (MIT Method)	Warp		1,441	1,536	1,484
.03 JAW @ 4 LBS	Fill		107	101	108
Flex Cycles (% Loss)	Warp	@ 15,000	90.39%	89.76%	90.11%
.03 JAW @ 4 LBS	Fill	@ 500	78.60%	79.80%	78.40%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)	@ 1200°F (SEAM AREA)		8.67%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing					

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Identification		10 (5,10)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight	As received		19.83	20.14	20.18
Oz/sq. yd.	Cleaned (Vacuum)		13.46	13.44	13.44
	Cleaned (Washed)		10.32	10.30	10.31
Thickness (inches)			.017		
Count			55X30	55X30	55X30
Weave			3X1 TW		
Yarn	Warp/Length		150 1/2 F		
System	Filing/Width		150 2/2 T		
Permeability	As received		1.61	1.60	1.58
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		21.9	22.3	22.4
	Cleaned (Washed)		60.7	63.2	63.2
Breaking	Warp/Length		187	191	190
Strength lbs/inch	Filling/Width		104	103	108
Breaking	Warp/Length	@ 250	25.20%	23.60%	24.00%
Strength, % Loss	Filling/Width	@ 130	20.00%	20.77%	16.92%
Mullen Burst (lbs/sq inch)			369	384	398
Mullen Burst % Loss		@ 525	29.71%	26.86%	24.91%
Flex Cycles (MIT Method)	Warp		1,961	2,387	2,009
.03 JAW @ 4 LBS	Fill		84	80	93
Flex Cycles (% Loss)	Warp	@ 15,000	86.93%	84.09%	86.61%
.03 JAW @ 4 LBS	Fill	@ 500	83.20%	84.00%	81.40%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	8.78%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing					

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Identification		18 (8,9)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight	As received		24.61	24.97	24.83
Oz/sq. yd.	Cleaned (Vacuum)		15.52	14.84	14.91
	Cleaned (Washed)		13.68	13.71	13.63
Thickness (inches)			.018		
Count			44X24	44X24	44X23
Weave			3X1 TW		
Yarn	Warp/Length		37 1/0 F		
System	Filing/Width		75 1/3 T/F		
Permeability	As received		1.73	1.64	1.65
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		18.3	18.2	18.7
	Cleaned (Washed)		54.8	56.6	55.2
Breaking	Warp/Length		420	418	439
Strength lbs/inch	Filling/Width		146	152	178
Breaking	Warp/Length	@ 550	23.64%	24.00%	20.18%
Strength % Loss	Filling/Width	@ 250	41.60%	39.20%	28.80%
Mullen Burst (lbs/sq inch)			474	501	493
Mullen Burst % Loss		@ 600	21.00%	16.50%	17.83%
Flex Cycles (MIT Method)	Warp		2,478	2,163	2,549
.03 JAW @ 4 LBS	Fill		358	369	513
Flex Cycles (% Loss)	Warp	@ 5,900	58.00%	63.34%	56.80%
	Fill	@ 2,000	82.10%	81.55%	74.35%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	1.97%		
Treatment Physical Type			NONE		
Treatment Chemical Type			T.T.		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing					

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Identification		19 (5,10)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight	As received		24.89	25.13	26.72
Oz/sq. yd.	Cleaned (Vacuum)		17.31	17.07	17.26
	Cleaned (Washed)		14.38	14.39	14.38
Thickness (inches)			.018		
Count			44X24	44X24	44X24
Weave			3X1 TW		
Yarn	Warp/Length		37 1/0 F		
System	Filing/Width	2 TEXTURIZED/1 FILAMENT	75 1/2 T/F		
Permeability	As received		1.66	1.63	1.40
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		21.3	21.5	21.4
	Cleaned (Washed)		40.2	39.7	39.8
Breaking	Warp/Length		461	458	470
Strength lbs/inch	Filling/Width		144	141	147
Breaking	Warp/Length	@ 550	16.18%	16.73%	14.55%
Strength % Loss	Filling/Width	@ 250	42.40%	43.60%	41.20%
Mullen Burst (lbs/sq inch)			543	538	518
Mullen Burst % Loss		@ 700	22.43%	23.14%	26.00%
Flex Cycles (MIT Method)	Warp		26,431	20,187	24,118
.03 JAW @ 4 LBS	Fill		593	618	821
Flex Cycles (% Loss)	Warp	@ 60,000	55.95%	66.35%	59.80%
.03 JAW @ 4 LBS	Fill	@ 5,000	88.14%	87.64%	83.58%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	9.01%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing					

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Identification		20 (5,10)	TOP	CENTER	BOTTOM
Fiber Content			GLASS/PTFE		
Weight Oz/sq. yd.	As received		19.94	19.16	18.92
	Cleaned (Vacuum)		15.39	15.44	15.43
	Cleaned (Washed)		15.10	15.08	15.07
Thickness (inches)			.019		
Count			44X24		
Weave			3X1 TW		
Yarn System	Warp/Length		37 1/0 F		
	Filing/Width	2 TEXTURIZED/1 FILAMENT	74 1/3 T/F		
Permeability CFM/sq ft @ .5" H_2O	As received		2.63	2.75	2.79
	Cleaned (Vacuum)		5.3	5.1	5.1
	Cleaned (Washed)		7.8	7.8	7.6
Breaking Strength lbs/inch	Warp/Length		561	564	553
	Filling/Width		246	251	247
Breaking Strength % Loss	Warp/Length	@ 550	0%	0%	0%
	Filling/Width	@ 250	1.60%	0%	1.20%
Mullen Burst (lbs/sq inch)			742	731	738
Mullen Burst % Loss		@ 700	0%	0%	0%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		21,078	19,652	23,381
	Fill		6,898	8,056	8,782
Flex Cycles (% Loss)	Warp	@ ESTIMATED	15.69%	21.39%	6.48%
	Fill	ESTIMATED	31.02%	19.44%	12.18%
% Extractable Matter	Solvent				
	Water				
Acid Alkaline (PH)					
% Ignition Loss (LOI)	W @ 1200°F (SEAM AREA)		3.88% (FILM NOT INCLUDED)		
Treatment Physical Type			SEE BELOW		
Treatment Chemical Type			A.F.		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming				
	Cuffing				
	Ring Cover				
Hardware Type					
Length (inches) Tension _____					
Diameter (inches) Tension _____					
Fabrication Rating					
Other Testing	SPECIAL LAMINATE		GORE-TEX		

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Identification		21 (5,10)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight Oz/sq. yd.	As received		17.21	16.83	16.91
	Cleaned (Vacuum)		12.48	12.47	12.63
	Cleaned (Washed)		9.98	10.07	10.05
Thickness (inches)			.017		
Count			55X30	55X30	55X30
Weave			3X1 TW		
Yarn System	Warp/Length		150 1/2 F		
	Filing/Width		150 2/2 T		
Permeability CFM/sq ft @ .5" H_2O	As received		2.61	2.55	2.58
	Cleaned (Vacuum)		20.1	20.4	19.8
	Cleaned (Washed)		59.8	59.4	60.3
Breaking Strength lbs/inch	Warp/Length		172	176	183
	Filling/Width		98	99	101
Breaking Strength % Loss	Warp/Length	@ 250	31.20%	29.60%	26.80%
	Filling/Width	@ 130	24.62%	23.85%	22.31%
Mullen Burst (lbs/sq inch)			339	340	345
Mullen Burst % Loss		@ 525	35.43%	35.38%	34.29%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		1,487	1,516	1,761
	Fill		68	71	85
Flex Cycles (% Loss) .03 JAW @ 4 LBS	Warp	@ 15,000	90.09%	89.89%	88.26%
	Fill	@ 500	86.40%	85.80%	83.00%
% Extractable Matter	Solvent				
	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	8.23%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension _____					
Diameter (inches) Tension _____					
Fabrication Rating					
Other Testing					

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			TOP	CENTER	BOTTOM
Identification		21 (8,10)			
Fiber Content			GLASS		
Weight Oz/sq. yd.	As received		19.64	19.62	19.61
	Cleaned (Vacuum)		13.58	13.59	13.54
	Cleaned (Washed)		10.18	10.19	10.20
Thickness (inches)			.017		
Count			55X30	55X30	55X30
Weave			3X1 TW		
Yarn System	Warp/Length		150 1/2 F		
	Filing/Width		150 2/2 T		
Permeability CFM/sq ft @ .5" H_2O	As received		1.74	1.68	1.71
	Cleaned (Vacuum)		22.0	21.6	21.7
	Cleaned (Washed)		63.4	63.1	62.8
Breaking Strength lbs/inch	Warp/Length		200	198	204
	Filling/Width		109	114	113
Breaking Strength % Loss	Warp/Length	@ 250	20.00%	20.80%	18.40%
	Filling/Width	@ 130	16.15%	12.30%	13.08%
Mullen Burst (lbs/sq inch)			494	491	518
Mullen Burst % Loss		@ 525	5.90%	6.48%	1.33%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		2,583	2,287	2,804
	Fill		91	86	97
Flex Cycles (% Loss)	Warp	@ 15,000	82.78%	84.75%	81.31%
	Fill	@ 500	81.80%	82.80%	80.60%
% Extractable Matter	Solvent				
	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	9.01%		
Treatment Physical Type			NONE		
Treatment Chemical Type			TEFLON B		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing					

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			TOP	CENTER	BOTTOM
Identification		22 (5,11)			
Fiber Content			GLASS		
Weight	As received		25.84	25.61	25.74
Oz/sq. yd.	Cleaned (Vacuum)		15.56	15.71	15.63
	Cleaned (Washed)		13.60	13.61	13.62
Thickness (inches)			.017		
Count			44X24	44X24	44X24
Weave			3X1 TW		
Yarn	Warp/Length		37 1/0 F		
System	Filing/Width	2 Text/1 Fil	75 1/3 F/I		
Permeability	As received		1.24	1.21	1.31
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		19.6	18.4	18.4
	Cleaned (Washed)		52.8	53.6	52.4
Breaking	Warp/Length		520	503	521
Strength lbs/inch	Filling/Width		202	221	262
Breaking	Warp/Length	@ 600	13.33%	16.17%	13.17%
Strength % Loss	Filling/Width	@ 300	32.67%	26.33%	12.67%
Mullen Burst (lbs/sq inch)			426	518	563
Mullen Burst % Loss			39.14%	26.00%	19.57%
Flex Cycles (MIT Method)	Warp		5,673	5,462	5,198
.03 JAW @ 4 LBS	Fill		1,154	1,307	1,441
Flex Cycles (% Loss)	Warp	@ 10,500	45.97%	47.98%	50.49%
	Fill	@ 5,000	72.92%	73.86%	71.18%
% Extractable	Solvent				
Matter	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	3.97%		
Treatment Physical Type			NONE		
Treatment Chemical Type			A.F.		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension					
Diameter (inches) Tension					
Fabrication Rating					
Other Testing					

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Identification		22 (8,11)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight Oz/sq. yd.	As received		24.87	25.13	24.51
	Cleaned (Vacuum)		15.18	14.72	15.03
	Cleaned (Washed)		13.65	13.64	13.64
Thickness (inches)			.018		
Count			44X24	44X24	44X23
Weave			3X1 TW		
Yarn System	Warp/Length		37 1/0 F		
	Filing/Width	2 TEXT/1 FILAMENT	75 1/3 T/F		
Permeability CFM/sq ft @ .5" H_2O	As received		1.73	1.75	2.01
	Cleaned (Vacuum)		20.9	21.2	20.8
	Cleaned (Washed)		57.5	56.4	57.3
Breaking Strength lbs/inch	Warp/Length		583	561	587
	Filling/Width		264	258	270
Breaking Strength % Loss	Warp/Length	@ 600	2.83%	6.50%	2.17%
	Filling/Width	@ 300	12.00%	14.00%	10.00%
Mullen Burst (lbs/sq inch)			624	583	659
Mullen Burst % Loss		@ 700	10.86%	16.71%	5.86%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		6,187	7,162	6,507
	Fill		1,873	1,561	2,317
Flex Cycles (% Loss)	Warp	@ 10,500	41.08%	31.79%	38.03%
	Fill	@ 5,000	62.54%	68.78%	53.66%
% Extractable Matter	Solvent				
	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	4.00%		
Treatment Physical Type			NONE		
Treatment Chemical Type			A.F.		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension _____					
Diameter (inches) Tension _____					
Fabrication Rating					
Other Testing					

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Identification		24 (8,16)	TOP	CENTER	BOTTOM	CUFF AREA
Fiber Content			NOMEX			
Weight	As received		7.73	7.81	7.78	
Oz/sq. yd.	Cleaned (Vacuum)		6.38	6.21	6.43	
	Cleaned (Washed)		5.36	5.37	5.37	
Thickness (inches)						
Count			80X72			
Weave			3X2 TW			
Yarn	Warp/Length		SINGLE			
System	Filling/Width		SINGLE			
Permeability	As received		3.29	3.30	3.25	
CFM/sq ft @ .5" H_2O	Cleaned (Vacuum)		28.8	29.4	28.9	
	Cleaned (Washed)		60.1	60.2	58.9	
Breaking	Warp/Length		55	57	56	
Strength lbs/inch	Filling/Width		44	43	43	
Breaking	Warp/Length	@ 168	67.26%	66.07%	66.67%	
Strength % Loss	Filling/Width	@ 145	69.55%	70.34%	70.34%	
Mullen Burst (lbs/sq inch)			140	143	144	174
Mullen Burst % Loss		@ 424	66.98%	66.27%	66.04%	58.96%
Flex Cycles (MIT Method)	Warp		3,187	3,362	3,619	3,844
.03 JAW @ 5 LBS	Fill		2,418	2,612	2,507	2,961
Flex Cycles (% Loss)	Warp	@ 98,874	96.78%	96.99%	96.40%	96.11%
.03 JAW @ 5 LBS	Fill	@ 86,071	97.19%	16.97%	97.09%	96.56%
% Extractable	Solvent					
Matter	Water					
Acid/Alkaline (PH)						
% Ignition Loss (LOI)						
Treatment Physical Type			NONE			
Treatment Chemical Type			A.R.			
% Elongation	Warp/Length					
% Shrinkage	Filling/Width					
Fabrication	Seaming	DOUBLE ROW	CHAIN			
	Cuffing	DOUBLE ROW	LOCK			
	Ring Cover					
Hardware Type						
Length (inches) Tension						
Diameter (inches) Tension						
Fabrication Rating						
Other Testing		SEWING THREAD	GORE-TEX			

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Identification		25 (8,9)	TOP	CENTER	BOTTOM
Fiber Content			GLASS		
Weight Oz/sq. yd.	As received		23.87	25.02	25.31
	Cleaned (Vacuum)		18.61	17.87	18.21
	Cleaned (Washed)		13.29	13.34	13.31
Thickness (inches)			.018		
Count			44X24	44X23	44X23
Weave			3X1 TW		
Yarn System	Warp/Length		37 1/0 F		
	Filing/Width	2 TEXT/1 FILAMENT	75 1/3 T/F		
Permeability CFM/sq ft @ .5" H_2O	As received		1.71	1.63	1.52
	Cleaned (Vacuum)		16.9	18.1	17.5
	Cleaned (Washed)		68.9	69.3	68.8
Breaking Strength lbs/inch	Warp/Length		403	418	374
	Filling/Width		148	141	152
Breaking Strength % Loss	Warp/Length	@ 550	26.73%	24.00%	32.00%
	Filling/Width	@ 250	40.80%	43.60%	39.20%
Mullen Burst (lbs/sq inch)			501	531	584
Mullen Burst % Loss		@ 600	16.50%	11.50%	2.67%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		1,461	1,507	1,442
	Fill		315	281	302
Flex Cycles (% Loss)	Warp	@ 5,900	75.24%	74.46%	75.56%
	Fill	@ 1,900	83.42%	85.21%	84.11%
% Extractable Matter	Solvent				
	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)	1.53%		
Treatment Physical Type			NONE		
Treatment Chemical Type			T.T.		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type					
Length (inches) Tension _____					
Diameter (inches) Tension _____					
Fabrication Rating					
Other Testing					

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Identification		26 (8,11)	TOP	CENTER	BOTTOM	FLEX LINE
Fiber Content			GLASS			
Weight Oz/sq. yd.	As received		24.98	25.16	25.01	
	Cleaned (Vacuum)		14.02	14.14	14.31	
	Cleaned (Washed)		13.74	13.76	13.75	
Thickness (inches)			.019			
Count			44X24			
Weave			3X1 TW			
Yarn System	Warp/Length		37 1/0 F			
	Filing/Width	2 TEXT/1 FILAMENT	75 1/3 T/F			
Permeability CFM/sq ft @ .5" H_2O	As received		1.68	1.57	1.59	
	Cleaned (Vacuum)		20.2	20.4	19.8	
	Cleaned (Washed)		67.5	68.9	68.1	
Breaking Strength lbs/inch	Warp/Length		347	358	387	
	Filling/Width		162	147	158	118
Breaking Strength % Loss	Warp/Length	@ 590	41.19%	39.32%	34.41%	-
	Filling/Width	@ 310	47.74%	52.58%	49.03%	61.94%
Mullen Burst (lbs/sq inch)			422	447	441	248
Mullen Burst % Loss		@ 865	51.21%	48.32%	49.02%	71.33%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		3,815	2,629	3,417	2,741
	Fill		835	961	814	318
Flex Cycles (% Loss)	Warp	@ 72,000	94.70%	96.35%	95.54%	96.19%
	Fill	@ 9,000	90.72%	89.32%	90.96%	96.67%
% Extractable Matter	Solvent					
	Water					
Acid/Alkaline (PH)						
% Ignition Loss (LOI)		@ 1200°F SEAM AREA	4.97%			
Treatment Physical Type			NONE			
Treatment Chemical Type			COF			
% Elongation	Warp/Length					
% Shrinkage	Filling/Width					
Fabrication	Seaming		CHAIN			
	Cuffing		LOCK			
	Ring Cover					
Hardware Type						
Length (inches) Tension _____						
Diameter (inches) Tension _____						
Fabrication Rating						
Other Testing						

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			TOP	CENTER	BOTTOM
Identification		26 (9,11)			
Fiber Content			GLASS		
Weight Oz/sq. yd.	As received		24.13	22.18	22.41
	Cleaned (Vacuum)		15.93	16.46	16.31
	Cleaned (Washed)		13.70	13.71	13.71
Thickness (inches)			.018		
Count			44X24		
Weave			3X1 TW		
Yarn System	Warp/Length		37 1/0 F		
	Filing/Width	2 TEXT/1 FILAMENT	75 1/3 T/F		
Permeability CFM/sq ft @ .5" H_2O	As received		1.98	2.13	2.01
	Cleaned (Vacuum)		21.8	21.3	19.8
	Cleaned (Washed)		72.4	70.2	68.5
Breaking Strength lbs/inch	Warp/Length		454	449	487
	Filling/Width		221	214	251
Breaking Strength % Loss	Warp/Length	@ 590	23.05%	23.90%	17.46%
	Filling/Width	@ 310	28.71%	30.97%	19.03%
Mullen Burst (lbs/sq inch)			648	643	657
Mullen Burst % Loss		@ 865	25.09%	25.66%	24.05%
Flex Cycles (MIT Method) .03 JAW @ 4 LBS	Warp		4,183	4,961	5,462
	Fill		861	697	814
Flex Cycles (% Loss)	Warp	@ 72,000	92.80%	93.11%	92.41%
	Fill	@ 9,000	90.43%	92.25%	90.96%
% Extractable Matter	Solvent				
	Water				
Acid/Alkaline (PH)					
% Ignition Loss (LOI)		@ 1200°F (SEAM AREA)			
Treatment Physical Type			NONE		
Treatment Chemical Type			COF		
% Elongation	Warp/Length				
% Shrinkage	Filling/Width				
Fabrication	Seaming	TRIPLE ROW	CHAIN		
	Cuffing	DOUBLE ROW	LOCK		
	Ring Cover				
Hardware Type			NONE		
Length (inches) Tension _____					
Diameter (inches) Tension _____					
Fabrication Rating					
Other Testing					